Southwest Fisheries Science Center
Administrative Report H-93-04

STATUS OF LOBSTER STOCKS IN THE NORTHWESTERN HAWAIIAN ISLANDS, 1992

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March 1993

NOT FOR PUBLICATION

ABSTRACT

In 1992, 260,000 spiny lobster and 164,000 slipper lobster were caught in 722,000 trap-hauls, for a combined annual catch-per-unit-effort (CPUE) of 0.59 lobster/trap-haul. This value was only 5% higher than the 1991 value, indicating that the lobster population in the Northwestern Hawaiian Islands (NWHI) has not recovered appreciably from the drop in CPUE that occurred in 1990. Results of fitting the 1983-92 NWHI commercial fishery data to a time-lagged dynamic production model suggested that lobster recruitment in the NWHI has fallen 50% since 1989. The 1992 spawning potential ratio was 0.37, within the range set by the Crustacean Fishery Management Plan (FMP) that calls for supplementary management measures to prevent recruitment overfishing. A CPUE index of exploited to unexploited biomass ratios indicated that spawning biomass in 1992 was 23% of the unexploited level. Forward simulation using the time lagged dynamic production model suggested that the NWHI lobster stocks will not have recovered sufficiently to allow a commercial fishery in 1993.

INTRODUCTION

Commercial exploitation of lobsters in the Northwestern Hawaiian Islands (NWHI) began in 1976, with one vessel fishing at Necker Island for spiny lobster (*Panulirus marginatus)*. During the years 1977-85, several more vessels entered the fishery, and by 1985, 16 vessels were fishing for spiny lobster and slipper lobster, (*Scyllarides squammosus*) in the NWHI.

Lobster landings peaked in 1984 and gradually declined during the years 1985 through 1990. A substantial decrease in lobster landings and catch-per-unit-effort (CPUE) in the NWHI in 1990 raised concern that fishing effort was excessive for the existing lobster population. Low lobster CPUE continued into the early part of 1991, prompting an emergency closure of the fishery from May through November 1991. An amendment (No. 7) to the Fishery Management Plan (FMP) was passed in early 1992, which created an annual 6-month closed season (January-June) and annual catch quota. The annual quota is set at a level that provides an economically viable CPUE (1.0 lobster/trap-haul), while protecting spawning stock biomass from overdepletion.

The pre-season quota estimate for the 1992 NWHI commercial season was calculated in February 1992 using the commercial CPUE from the previous year and long-term average lobster recruitment and mortality estimates. The pre-season quota was forecast at 750,000 lobsters (Haight and Polovina 1992); however, a research cruise to the NWHI in June 1992, indicated that recruitment in the NWHI had not improved by mid-1992. Based on the CPUE information from the first month of the commercial fishery, the final quota was set at 438,000 lobsters.

This, the eighth annual report on the status of lobster stocks in the NWHI, reports on current lobster population research, and attempts to use research and commercial logbook data from 1983 through 1992 to forecast changes in the NWHI lobster population in response to various environmental and exploitation scenarios.

RESEARCH AGE-FREQUENCY DATA

The NOAA ship *Townsend Cromwell* conducted research trapping operations at Lisianski Island, Maro Reef, and Necker Island from June 4 to July 3, 1992. Length frequency data were collected at quadrats standardized temporally, spatially, and by gear type at Maro Reef and Necker Island. Exploratory research trapping for spiny lobster juveniles was conducted in shallow lagoon areas of Lisianski Island and Maro Reef. Length frequencies of spiny lobster were converted to age frequencies by applying a growth curve estimated by Polovina and Moffitt (1989). Based on this growth curve, recruitment of spiny lobsters to the fishery occurs at approximately age 3. Age specific CPUE values were calculated by dividing the total number of spiny lobster in each age class by the total number of traps fished at each bank.

A dramatic reduction in research CPUE values of all age classes was first documented at Maro Reef in 1990 (Polovina 1991). This trend persisted through 1991 and 1992 (Fig. 1). Fishing effort at Maro Reef has been comparatively low during this period. Prior to 1990, CPUE values were highest for age-3 lobster; however, since 1990, the older age classes appear to account for a greater proportion of the CPUE. Lobster size frequencies from the NWHI commercial fishery in 1992 are consistent with this trend (Fig. 2).

Research CPUE values in 1992 for all age classes at Necker were within the range of CPUE values over the past several years for all age classes (Fig. 3); however, there has been a general decline in age-3 CPUE since 1988. The CPUE values for age-2 lobster at Necker Island have been relatively high throughout the time series, reaching the highest level in 1991. To determine if age-2 CPUE at Necker Island could be used as a predictor of commercial spiny lobster catch 1 year later, the Necker Island age-2 research CPUE was compared with commercial spiny lobster catch in the next year using Spearman rank correlation analysis. There was no significant correlation between the two variables, indicating that other factors may be influencing the relationship. There is some evidence that after release from a fishing vessel, spiny lobster are vulnerable to predation by large Carangids during the period they swim or float toward the benthos (Gooding 1985). However, the impact of this type of mortality on lobster population dynamics remains unclear.

COMMERCIAL FISHERY DATA

Because of the implementation in April 1992 of Amendment 7 to the crustacean FMP, the NWHI lobster fishery was closed during the months of May and June. The fishery reopened July 1, 1992 and continued through the end of the season (December 31, 1992). Commercial catch and effort data from the first month of the fishing season were used in the CPUE based quota model to calculate a final annual quota of 438,000 lobster for 1992.

During the 1992 July-December fishing season, 353,212 lobster (81% of the final quota) were caught in 582,801 trap-hauls for an average fishing season CPUE of 0.61 lobster/trap-haul. Total annual NWHI lobster catch (January-April, July-December) was 424,445 lobster (97% of the final quota) in 721,682 trap-hauls, for an average annual CPUE of 0.59 lobster/trap-haul. Annual catch and effort data (1983-92) are presented in Table 1 and Figure 4.

The average annual CPUE value for 1992 is only 5% higher than the 1991 annual CPUE value, indicating that the NWHI lobster stocks are not rapidly recovering.

Based on commercial logbook data, sublegal lobsters accounted for an estimated 57% of the total catch at Necker Island and Gardner Pinnacles and 22% of the total catch at Maro Reef.

LOBSTER POPULATION MODEL

To model changes in lobster population abundance in the NWHI, commercial fishery data from 1983 through 1992 were used in a time lagged dynamic production (TLDP) model that expresses the monthly total number of exploitable lobsters (N_t) as a function of the number of exploitable lobster in the previous month (N_{t-1}) adjusted for natural mortality, catch, and recruitment in the previous month as:

$$N_t = N_{t-1}e^{-m/12} - C_{t-1}+R/12, \qquad (1A)$$

where m is the annual instantaneous natural mortality, C is the monthly catch and R is the annual recruitment to the fishery. The model-based estimate of N_t was then converted to a CPUE value by multiplying by the catchability (q):

$$CPUE_t=qN_t. \qquad (1B)$$

Model based parameters (m, q, R) were estimated using an iterative non-linear least squares method that minimizes the residual sums of squares. The model assumes constant recruitment and catchability.

To create a valid time series of CPUE data that could be used in Equations (1A) and (1B), monthly catches of both lobster species were pooled across all banks. This was necessary due to fluctuations in fishery dynamics resulting from temporal and spatial changes in fleet effort and primary target species. The model was fit to the pooled commercial CPUE data from 1983 through 1992. The resulting parameter estimates were: R = 1.675×10^6, m = 0.456, q = 7.32×10^{-7}. Based on these parameters, under average conditions an estimated 1.67 million lobster recruit to the fishery annually, with a survival rate in the absence of fishing of approximately 63% per year. Fishing mortality (F) under 721,682 trap-hauls was estimated to be 0.53. Using the 1992 mean commercial CPUE value of 0.61 spiny lobster/trap-haul, the exploitable spiny lobster population in the NWHI was estimated to be 833,000 individuals during the 1992 fishing season.

The fit of the model to the commercial data is quite good for the years 1983 through 1989; however, beginning with the year

1990, the model consistently predicts higher monthly CPUE values than those realized by the commercial fishery (Fig. 5). To estimate the change in lobster productivity beginning in the year 1990, the model was run again with variable recruitment while holding q and m constant, as it was assumed that the divergence reflected a change in recruitment and not in natural mortality or catchability. The results of this type of analysis indicated that the lobster population had undergone a 50% reduction in lobster recruitment during the late 1980s (Fig. 6). This model will be referred to as TLDP(50), which incorporates a 50% reduction in annual lobster recruitment.

For comparison, a Ricker (1975) stock/recruitment relationship was incorporated in the TLDP model, and fit to the same data series. This approach did not fit the data quite as well but also estimated reduced recruitment after 1989 due to reduced spawning stock biomass during the 1986-1989 period (Fig. 7).

To provide an estimate of interannual changes in spiny lobster recruitment, the biological parameters from the TLDP model were used with annual commercial catch and effort data in the following formula:

$$R_t = C_t/[(qf_t/m+qf_t)(1-e^{-qft-m})], \qquad (2)$$

(Hilborn and Walters 1992) where R_t is the recruitment of spiny lobster to the fishery in a given year, C_t is the commercial catch in the same year and f_t is the effort. This method indicates that recruitment of age-3 lobster was constant from 1983 through 1989, and then dropped rapidly, declining from approximately 2 million lobster/year in 1984-89 to 1 million lobster/year in 1990-1992 (Fig. 8).

SPAWNING STOCK BIOMASS

The biological parameters estimated by fitting Equations (1A) and (1B) to commercial CPUE data were used with the 1992 commercial fishing effort in a standard yield per recruit model to estimate the spawning stock biomass per recruit (SSBR) resulting from the 1992 commercial fishing pressure. This value is compared to a pre-exploitation SSBR value to calculate a measure of estimated spawning success or spawning potential ratio (SPR). This value, which is simply the exploited SSBR to unexploited SSBR ratio, is used by the WPRFMC to determine if the NWHI lobster stocks are approaching a level of recruitment overfishing. Goodyear (1989) suggests that for some stocks, recruitment overfishing may occur when the SPR value falls below 0.20. The WPRFMC has adopted a SPR value of 0.20 as the minimum threshold for the NWHI lobster fishery.

The result of fitting the SSBR model to the commercial fishing effort in 1992 (721,000 trap-hauls) results in an SPR value of 0.37, which is within the range (0.2 to 0.5) set by Amendment 6 of the Crustacean FMP that flags the need for supplementary management measures to prevent recruitment overfishing. While a SPR value of 0.37 indicates that under average recruitment conditions, 721,000 trap-hauls would not be excessive, it must be noted that the parameters in the SSBR model are based on a long-term average of population conditions and do not reflect interannual recruitment fluctuations.

An alternate approach, if research CPUE data are available for a given year, is to calculate an index of spawning stock biomass based on the ratio of the current year's spawning stock biomass (kg/trap-haul) to unexploited spawning stock biomass. The ratio of spawning stock biomass in 1992 to pre-exploitation levels is given in Table 2. Spawning biomass at Necker Island and Maro Reef in 1992 was approximately 23% of the pre-exploitation level.

1993 COMMERCIAL FISHERY QUOTA METHODOLOGY

The NWHI commercial lobster fishery quota is set at a level that, while allowing the stocks to rebound, would permit an annual average fleet CPUE of 1.0 lobsters per trap-haul as required by Amendment 7 of the crustacean FMP.

The biological production estimates of the best fit of the TLDP(50) model were used to determine the number of lobsters which could be taken under present recruitment conditions while allowing the stocks to rebound to a sustainable level and provide an average combined legal spiny and slipper CPUE of 1.0 during the fishing season. The resulting quota equation is as follows:

$$\text{Quota}_i = \text{Catch}_{(opt)} + [N_i - N_{(opt)}], \tag{3A}$$

where Quota_i = the combined spiny and slipper lobster quota in year i, $\text{Catch}_{(opt)}$ = 220,000 and $N_{(opt)}$ = 1,366,000. N_i is determined from the equation:

$$N_i = \text{CPUE}_i/q, \tag{3B}$$

where q is a fishery independent estimate of catchability, and CPUE_i is the combined legal spiny and slipper catch-per-unit-effort at the beginning of a respective fishing season. CPUE_i may be derived from research or fishery data.

PRELIMINARY QUOTA FORECAST

To provide a preliminary estimate of the July - December 1993 NWHI commercial lobster quota, the best fit of the TLDP(50) model was used to estimate a CPUE value for July 1993 ($CPUE_i$). The estimated CPUE value was then used in Equations (3B) and (3A) to provide a preliminary 1992 NWHI commercial spiny and slipper lobster quota forecast. The results of this analysis indicated that lobster population will not have recovered sufficiently by July 1993 to allow a commercial fishery that would attain an average CPUE of 1.0 lobster/trap-haul during the 1993 fishing season. Therefore, the 1993 preseason quota forecast is 0 lobsters (90% confidence interval 0 to 271,000 lobsters).

A final in-season quota will be determined from Equations (3B) and (3A), where $CPUE_i$ is estimated from a combination of pre-season research data and commercial logbook data from the first month of fishing. Research and commercial CPUE data are highly correlated (Haight and Polovina 1992); therefore, the estimate of $CPUE_i$ used in Equation (3B) may be adjusted using research data to account for uneven commercial effort during July of any specific year.

Although the final estimate of $CPUE_i$ may differ from the pre-season estimate as derived from Equation (1), the relationship between $CPUE_i$ and the final $Quota_i$ as derived in Equation (3A) is linear and can be used to predict the final in-season $Quota_i$ based on any given $CPUE_i$ as derived from commercial and research data at the beginning of the July-December NWHI lobster season (Fig. 9).

FORWARD SIMULATION MODEL

A stochastic recruitment variable was incorporated into Equation (1A-B) to simulate the response of lobster recruitment to a fluctuating environment. The residual variance from the TLDP(50) model was used to generate a random log-normal distribution of modified annual recruitment estimates. Seventy-five simulations were run for each year of the forward simulation, which allowed confidence limits around the recruitment estimates to be calculated. The resulting average July CPUE values were then used in Equation (3A-B) to calculate the respective annual commercial quota, and this catch level (C_t) was used in the model for the next simulation run. Recruitment and catch levels were simulated 8 years into the future (year 2000) (Fig. 10). The TLDP(50) model predicts that the lobster population will take at least 2 years to rebuild to sustainable levels, and after that time the average NWHI commercial quota will be ~220,000 lobsters; it could however be as high as 600,000 lobsters. It must be noted that because of lower recruitment, the model predicts that to maintain an annual average CPUE of 1.0 lobster/trap haul the fishery runs a 30% risk of closure in any given year.

RESEARCH LARVAL DATA

To evaluate changes in larval lobster distribution and abundance, a series of nocturnal surface trawls was conducted at Maro Reef, Necker Island, and Lisianski Island in 1989 and 1992.

Trawling was done north and south of each of the above locations approximately 30-40 km offshore of the 200 m isobath. Trawl duration was approximately 2 hours. For analysis, late-stage spiny lobster phyllosoma (stages VI-IX) from all locations were pooled, and the mean occurrence was calculated from all stations combined. Mean number of phyllosoma present in the trawls dropped by 80% in 1992, relative to the number occurring in the 1989 sample. To determine if this reduction was related to a reduction in the parental lobster stock, the numbers of phyllosoma caught in the trawls were compared with the spawning stock biomass of spiny lobster in the previous year (spiny lobster larval duration is approximately 1 year). There was good concordance between the reduction in phyllosoma and the parental stock in the previous year; the phyllosoma dropped 80% between 1989 and 1992, and spawning biomass dropped 70% between the 1988 and 1991 (Table 3). This series of trawl stations will be continued in the future, creating a time series to evaluate the efficacy of using larval surveys as a recruitment forecast.

OCEANOGRAPHIC RELATIONSHIPS

Research by personnel at the NMFS Honolulu laboratory in 1990-91 suggested that recruitment of spiny lobster to portions of the NWHI may be influenced by changes in meso-scale oceanographic conditions that affect lobster larvae advection and total system productivity. A strong correlation between the Maro Reef/Necker Island catch ratio and sea-level difference between French Frigate Shoals and Midway Island, led to the prediction that recruitment at Maro Reef would improve in 1992 (Polovina and Mitchum 1992). By the end of 1992, it was clear that while the catch ratio followed the trend predicted by the sea-level data (Fig. 11), overall recruitment at Maro Reef remained low. It appears that the above relationship is related to the spatial distribution of lobster recruitment rather than recruitment magnitude.

DISCUSSION

Recent research by personnel at the NMFS Honolulu Laboratory and researchers at various Pacific Basin environmental institutions suggests that the Pacific Ocean undergoes long-term regime shifts that can affect localized biological system productivity. In the NWHI, declines in seabird, monk seal, reef fish and lobster populations indicate that the area has undergone a change of state and may now be in a period of lower productivity (Polovina and Mitchum in prep.). Because of changes in system productivity and reduced spawning biomass, it is hypothesized that the lobster population must be exploited at lower levels in the future than during the 1983-89 period.

Spawning stock biomass at Maro Reef has fallen drastically since 1988 and continued to decline in 1992. The relationship between spawning biomass and lobster recruitment to the fishery is unclear; however, low spawning biomass index values, in combination with the age specific CPUE data, indicate biological recruitment fluctuations and fishery exploitation have substantially reduced the spawning biomass in the NWHI. Therefore, the most conservative management action would be to extend the closed season through June 1994 to allow recovery of the lobster spawning stock biomass.

REFERENCES

Gooding, R. M.
1985. Predation on released spiny lobster, *Panulirus marginatus*, during tests in the Northwestern Hawaiian Islands. Mar. Fish. Rev. 47(1):27-35.

Goodyear, C. P.
1989. Spawning stock biomass per recruit: the biological basis for a fisheries management tool. ICCAT Working Doc. SCRS/89/82. 10 p.

Haight, W. R., and J. Polovina.
1992. Status of lobster stocks in the Northwestern Hawaiian Islands, 1991. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-92-02, 19 p.

Hilborn, R. H., and C. Walters.
1992. Quantitative fisheries stock assessment. Choice, dynamics and uncertainty. Routledge, Chapman & Hall, Inc., New York City, 570 p.

Polovina J. J.
1991. Status of lobster stocks in the Northwestern Hawaiian Islands, 1990. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep. H-91-04. 16 p.

Polovina J. J., and G. T. Mitchum.
In prep. Responses of oceanography and marine ecosystems in the North Pacific to the 1977-88 climatic event.

1992. Variability in spiny lobster Panulirus marginatus recruitment and sea level in the Northwestern Hawaiian Islands. Fish. Bull., U.S. 90:483-493.

Polovina J. J., and R. B. Moffitt.
1989. Status of lobster stocks in the Northwestern Hawaiian Islands, 1988. Honolulu Lab., Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-89-03, 10 p.

Ricker, W. E.
1975. Computation and interpretation of biological statistics of fish populations. J. Fish. Res. Board Can. Special Bulletin 191, 382 p.

Table 1. Annual landings of spiny and slipper lobster (1,000's), trapping effort (1,000's trap-hauls), and the percentage of spiny lobster in the landings, 1983-1992.[a]

Year	Spiny lobster	Slipper lobster[b]	Total lobster	Effort	CPUE	Total spiny lobster
1983[c]	158	18	176	64	2.75	90
1984	677	207	884	371	2.38	78
1985	1,022	900	1,902	1,041	1.83	57
1986	843	851	1,694	1,293	1.31	54
1987	393	352	745	806	0.92	57
1988	888	174	1,062	840	1.26	84
1989	944	222	1,166	1,069	1.09	81
1990	591	187	777	1,182	0.66	76
1991[d]	131	35	166	296	0.56	79
1992[e]	260	164	424	722	0.59	61

[a]Data are provided to the National Marine Fisheries Service as required by the Crustacean Fishery Management Plan of the Western Pacific Regional Fishery Management Council and are compiled by the Fishery Management Research Program, Honolulu, Laboratory.

[b]Slipper lobster landings, 1984-87 are 72% of those reported. The adjustment was made to account for a minimum size change in 1987.

[c]April-December 1983.

[d]January-May, November-December 1991

[e]January-April, July-December 1992

Table 2. An index of spawning stock biomass (kg/trap-night) for spiny lobster.

	Index by year						
	1977	1987	1988	1990	1991	1992	1992/1977
Necker Island	2.45	0.83	1.24	0.65	0.65	0.88	**0.35**
Maro Reef	2.14	1.74	1.71	0.36	0.20	0.16	**0.08**
Mean	2.29	1.29	1.48	0.51	0.43	0.52	**0.23**

Table 3. Spawning stock biomass and larval abundance indexes.

Date	Spawning stock biomass index (kg/trap-haul)	Date	Late stage larval abundance index (#/tow) (95% C.I.)
June 1988	1.48	June 1989	87 (46-167)
June 1991	0.43	June 1992	18 (11-29)

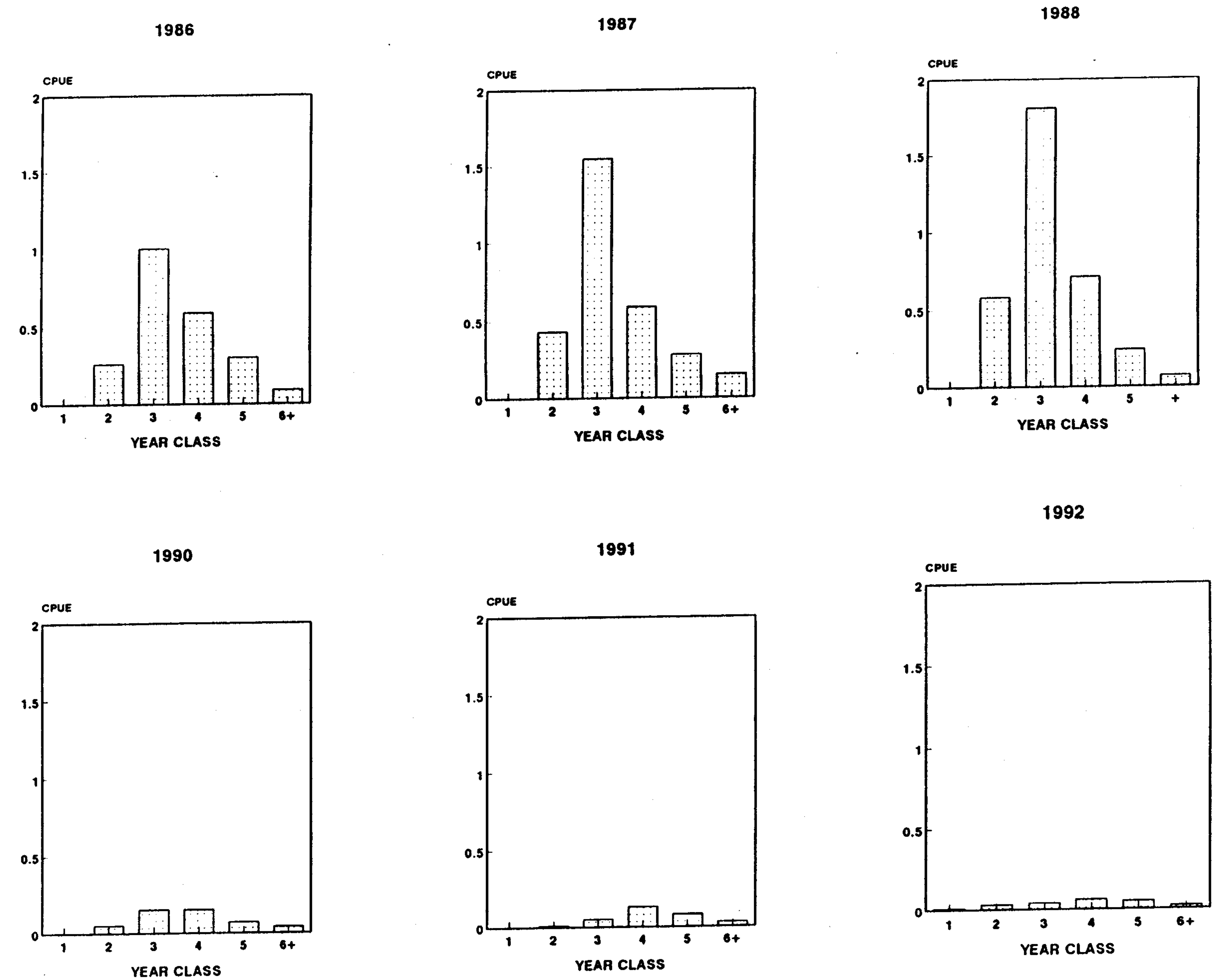

Figure 1. Catch-per-unit-effort for each age class of spiny lobster, Maro Reef, 1986-88, 1990-92

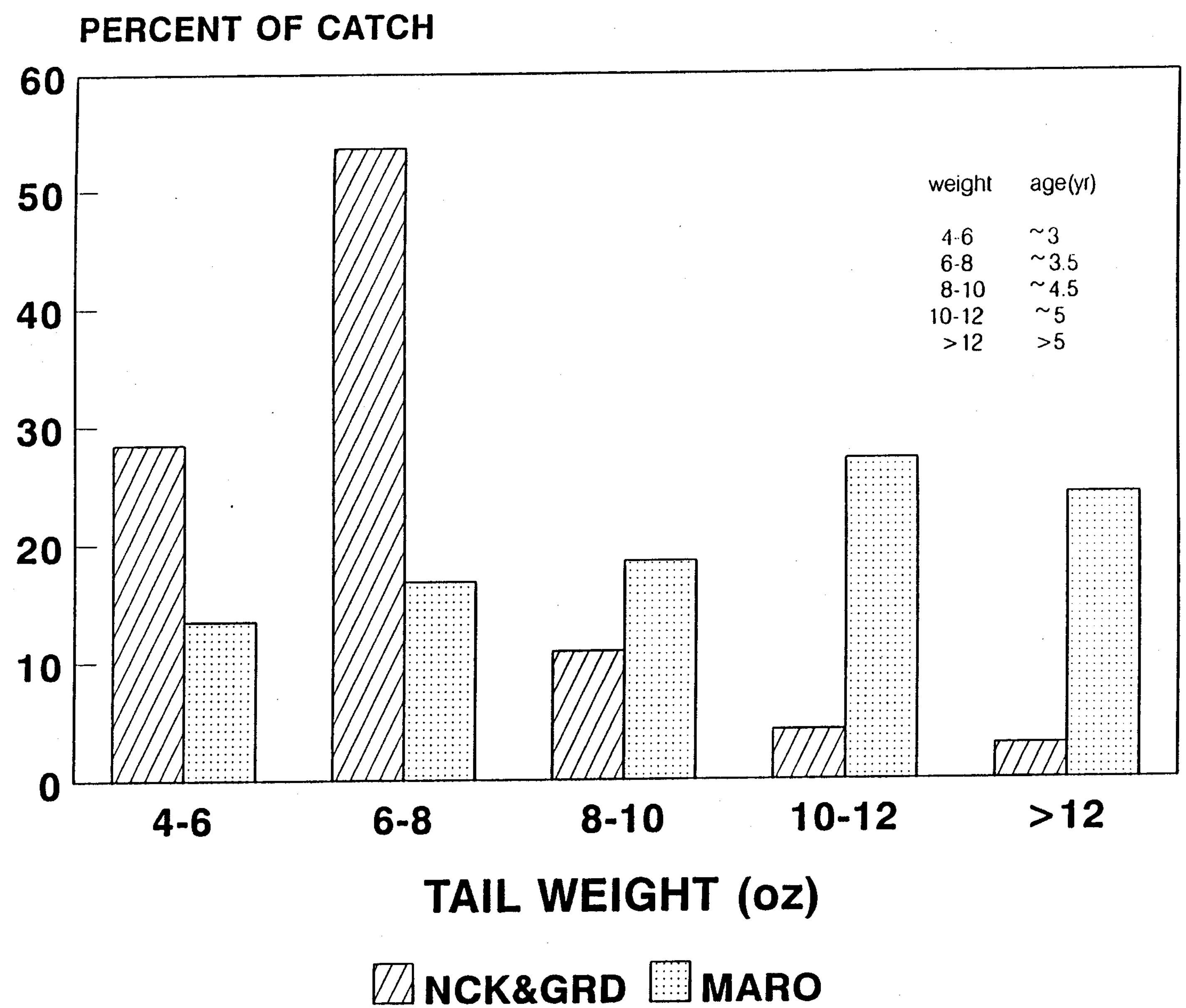

Figure 2. Tail weight frequency distribution from the commercial fishery in 1992. (Maro Reef, Necker Island+Gardner Pinnacles)

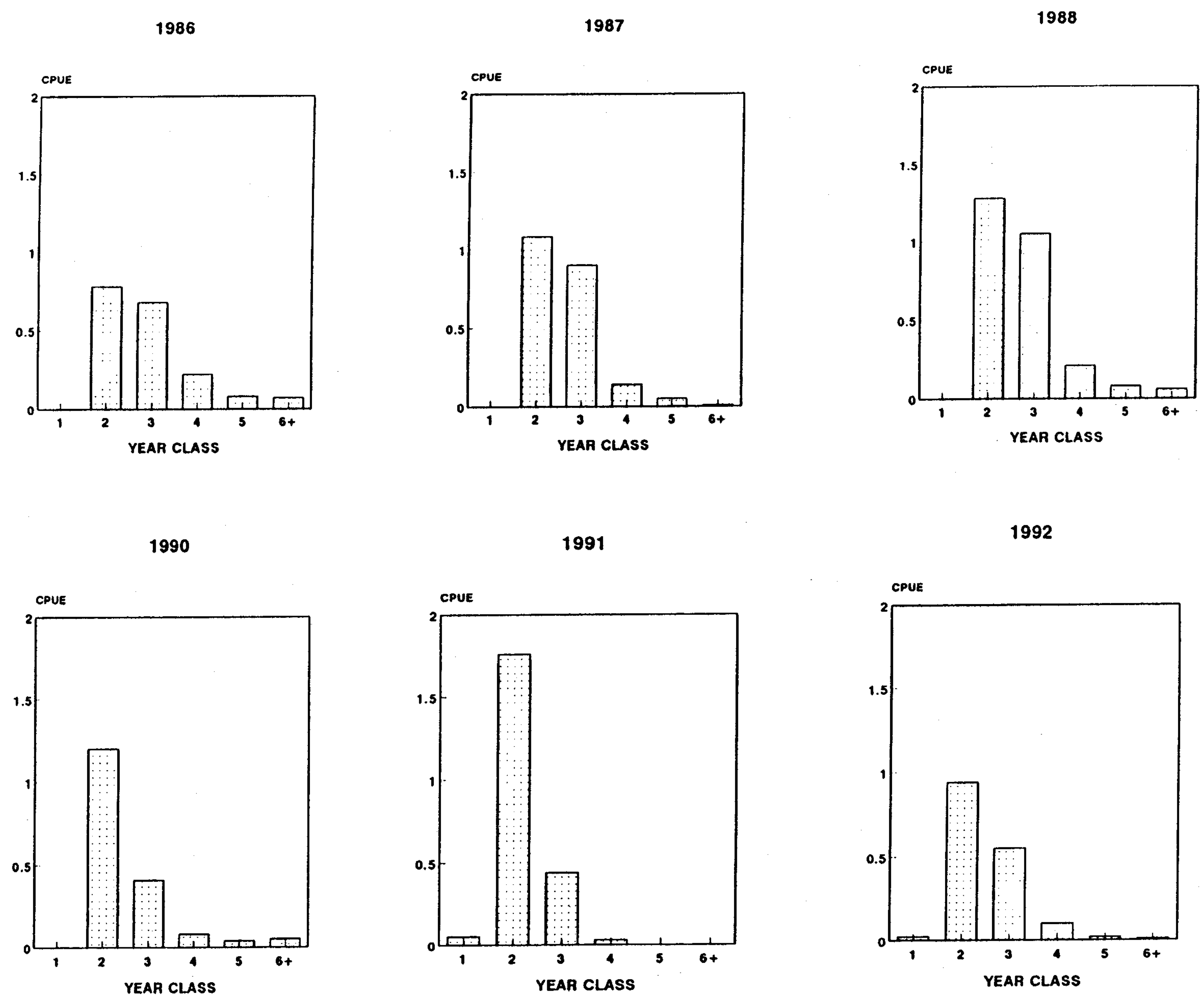

Figure 3. Catch-per-unit-effort for each age class of spiny lobster, Necker Island, 1986-88, 1990-92

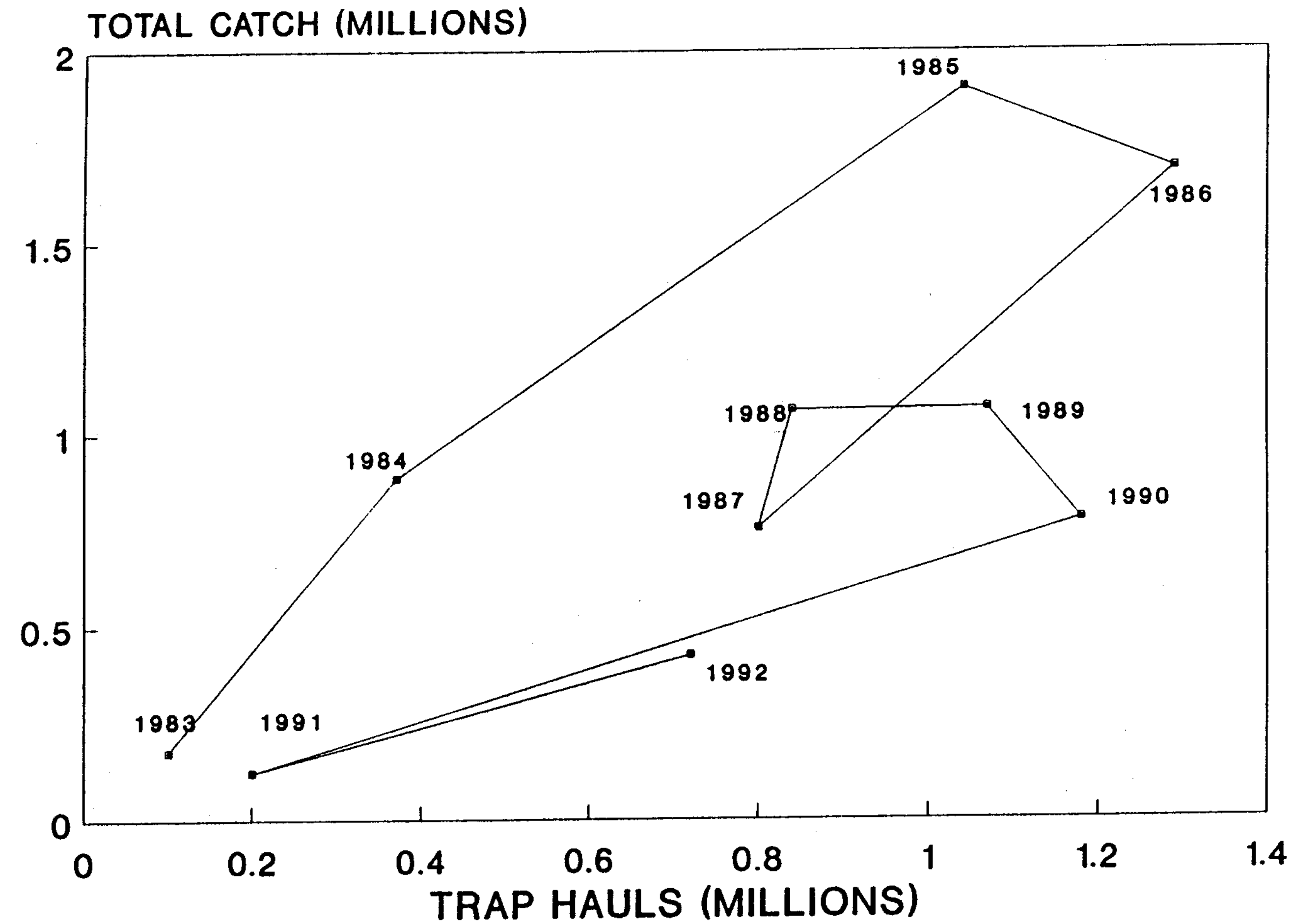

Figure 4. Catch and effort, from commercial logbooks, for combined Northwestern Hawaiian Island Banks, 1983-92.

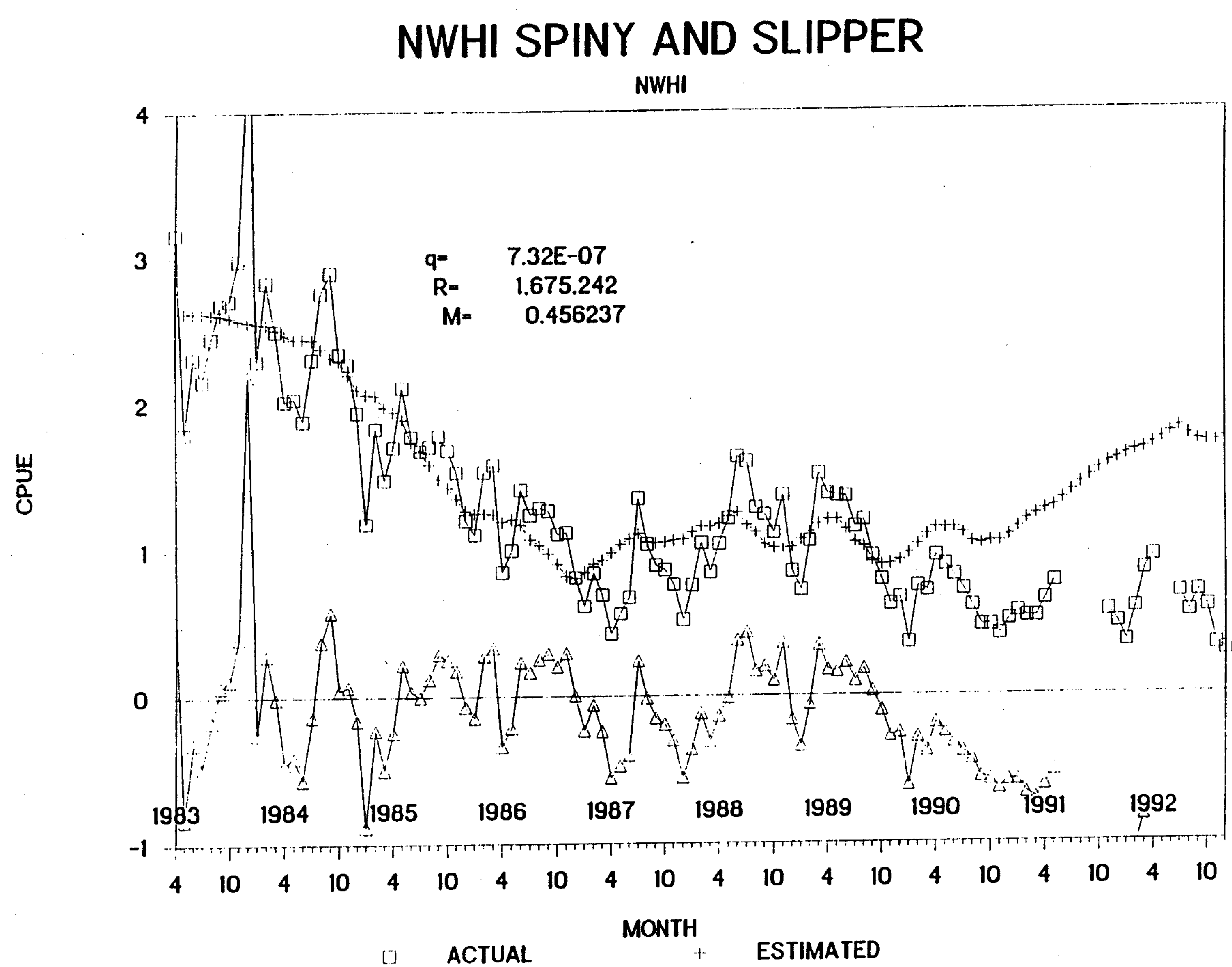

Figure 5. Monthly catch-per-unit-effort (CPUE) and fit of the TLDP model for spiny and slipper lobsters based on commercial fishery data, 1983-92. Residuals are the difference between actual and predicted CPUE values.

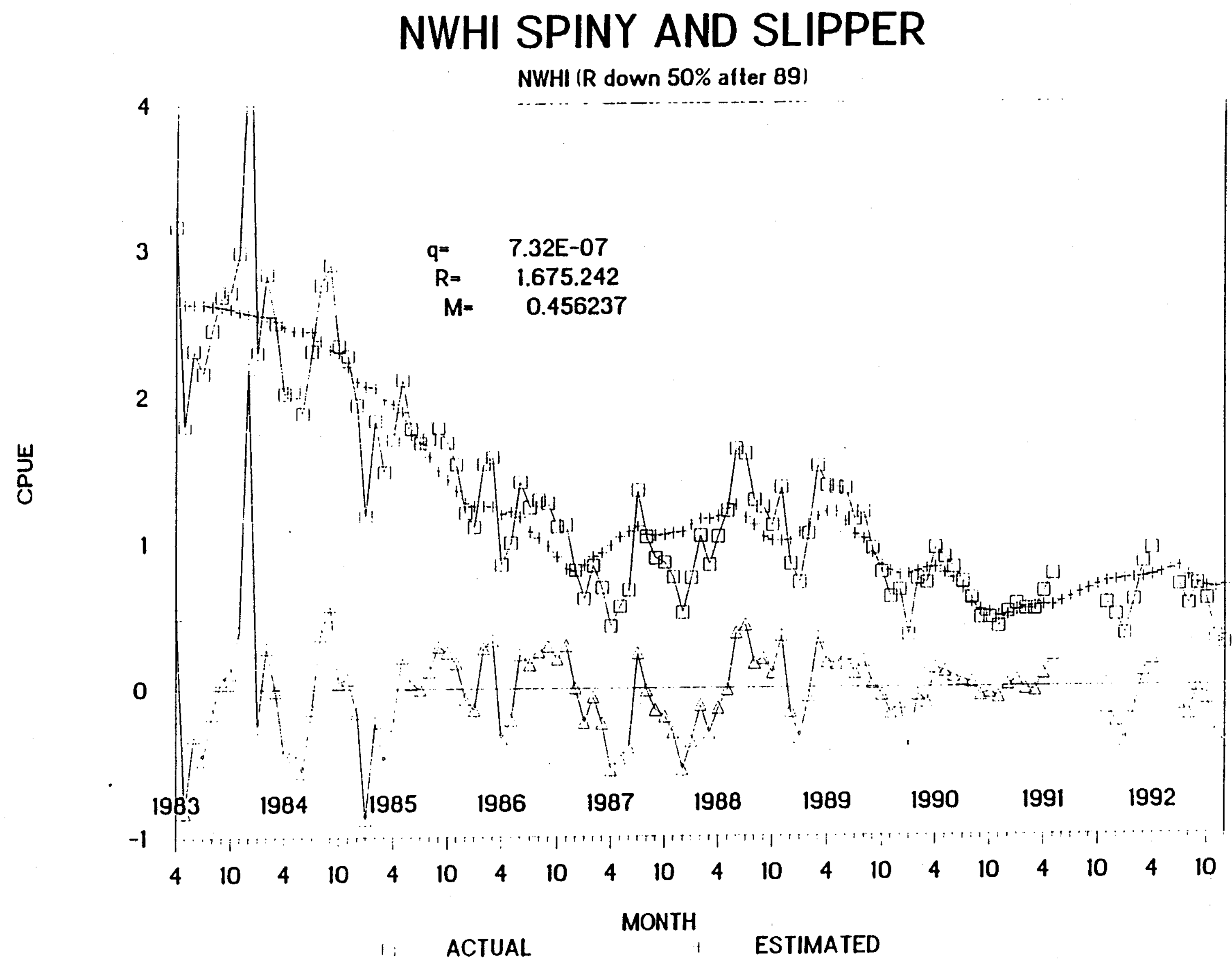

Figure 6. Monthly catch-per-unit-effort (CPUE) and fit of the TLDP(50) model for spiny and slipper lobsters based on commercial fishery data, 1983-92. Residuals are the difference between actual and predicted CPUE values.

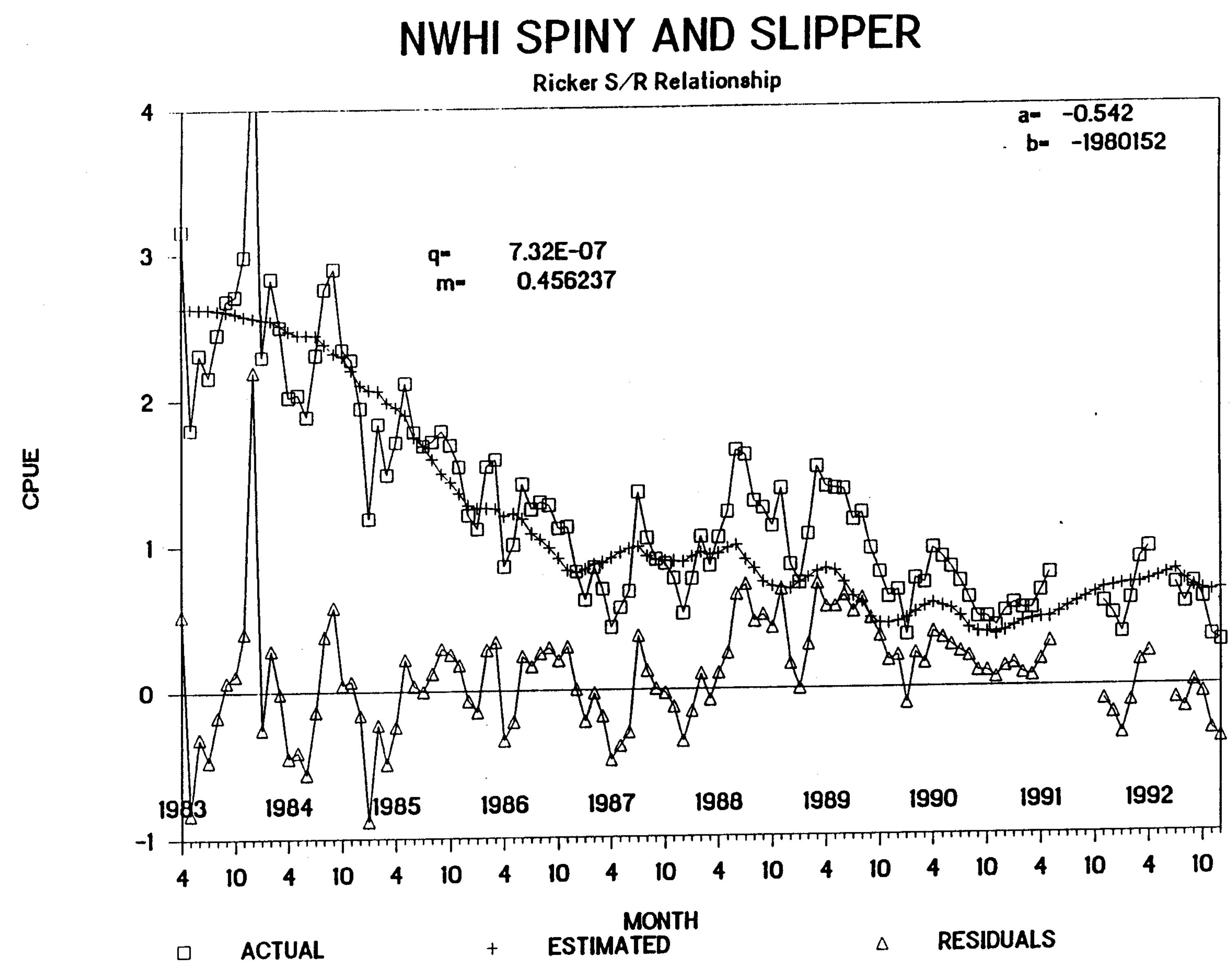

Figure 7. Monthly catch-per-unit-effort (CPUE) and fit of the Ricker spawner/recruit TLDP model for spiny and slipper lobsters based on commercial fishery data, 1983-92. Residuals are the difference between actual and predicted CPUE values.

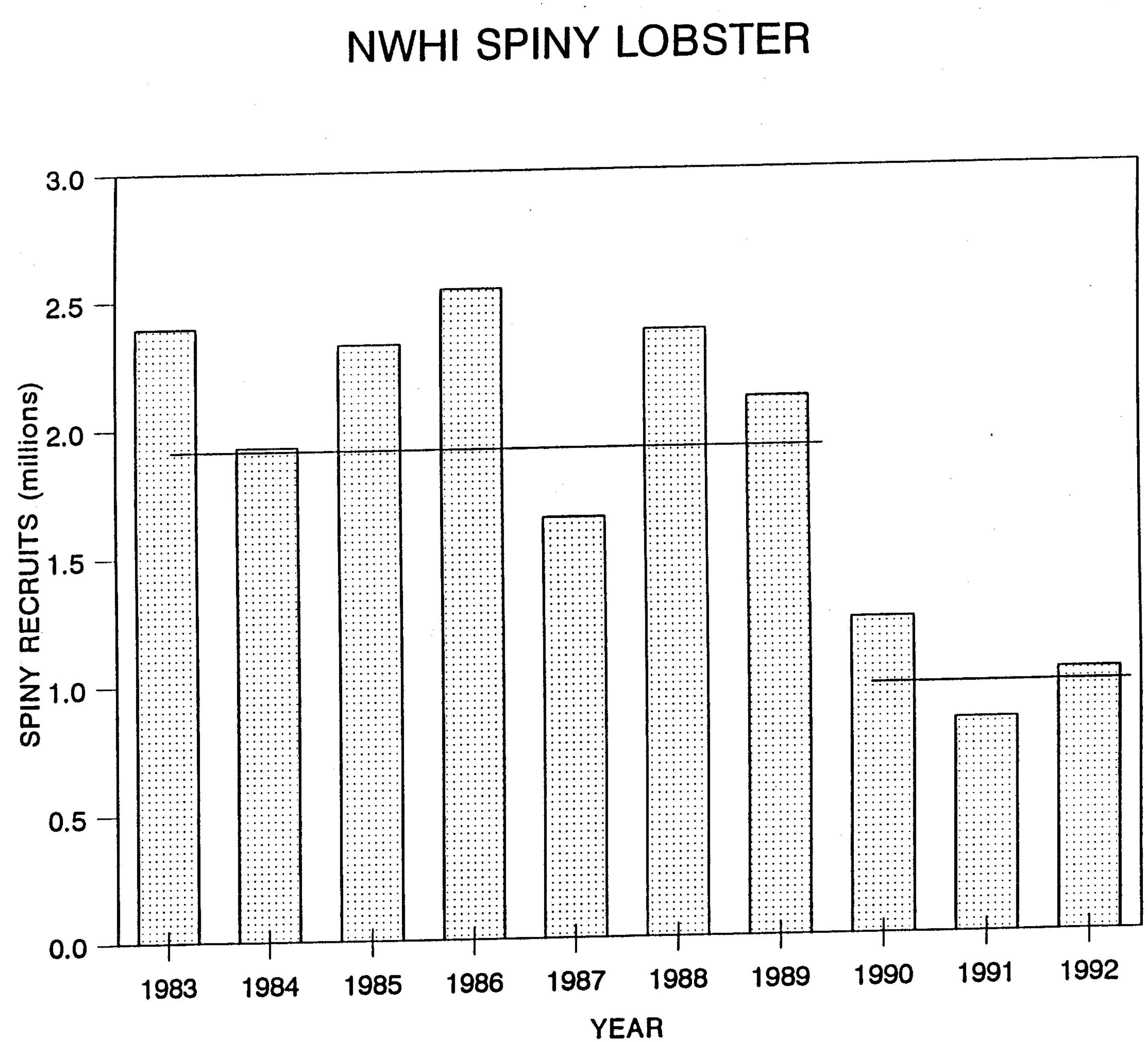

Figure 8. Estimated annual recruitment of age-3 spiny lobster to the Northwestern Hawaiian Islands (NWHI) fishery 1983-92. Horizontal lines indicate the average annual recruitment for the years 1983-89 and 1990-92.

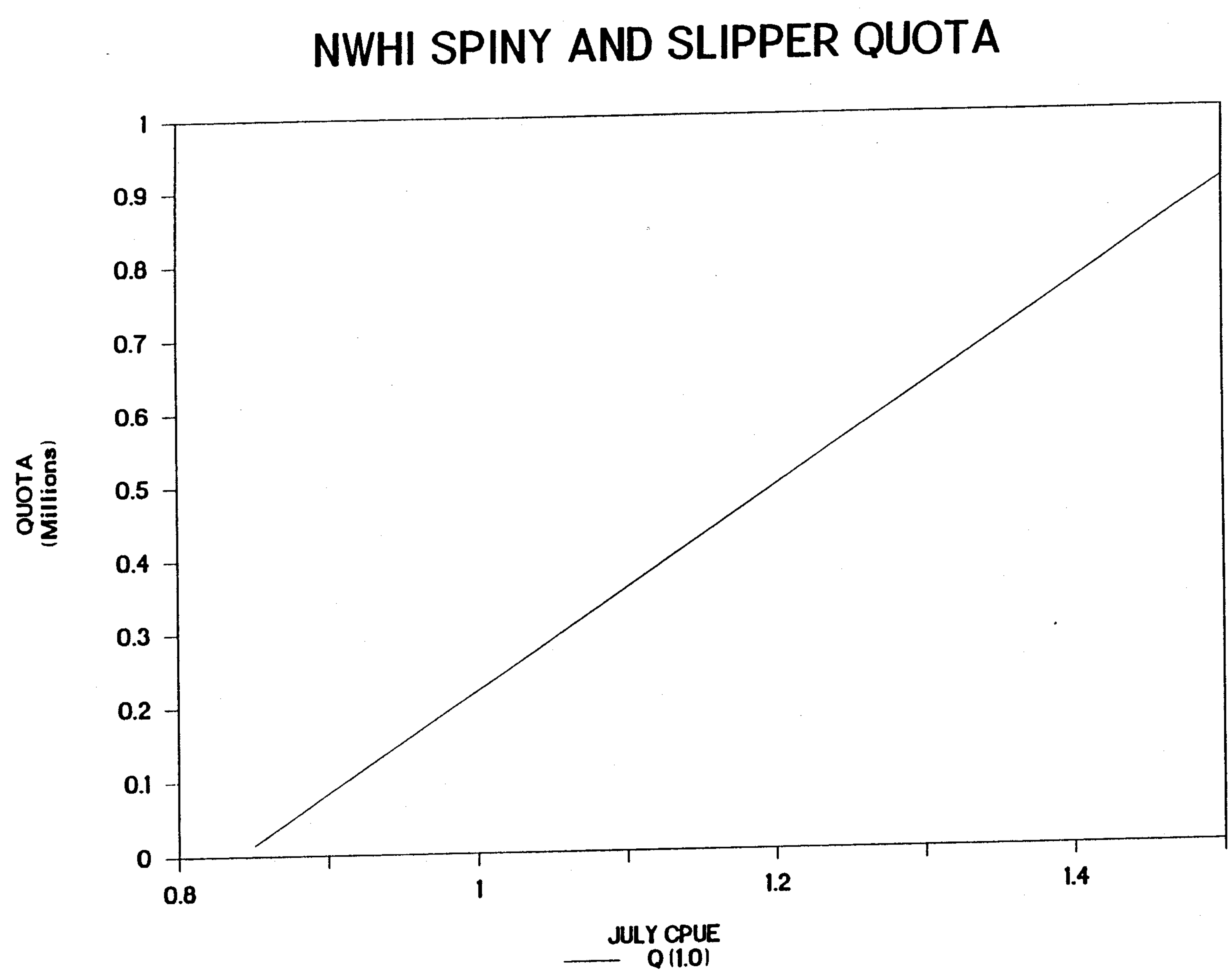

Figure 9. Relationship between catch-per-unit-effort and commercial quota as defined in Amendment 7 of the Crustacean Fishery Management Plan

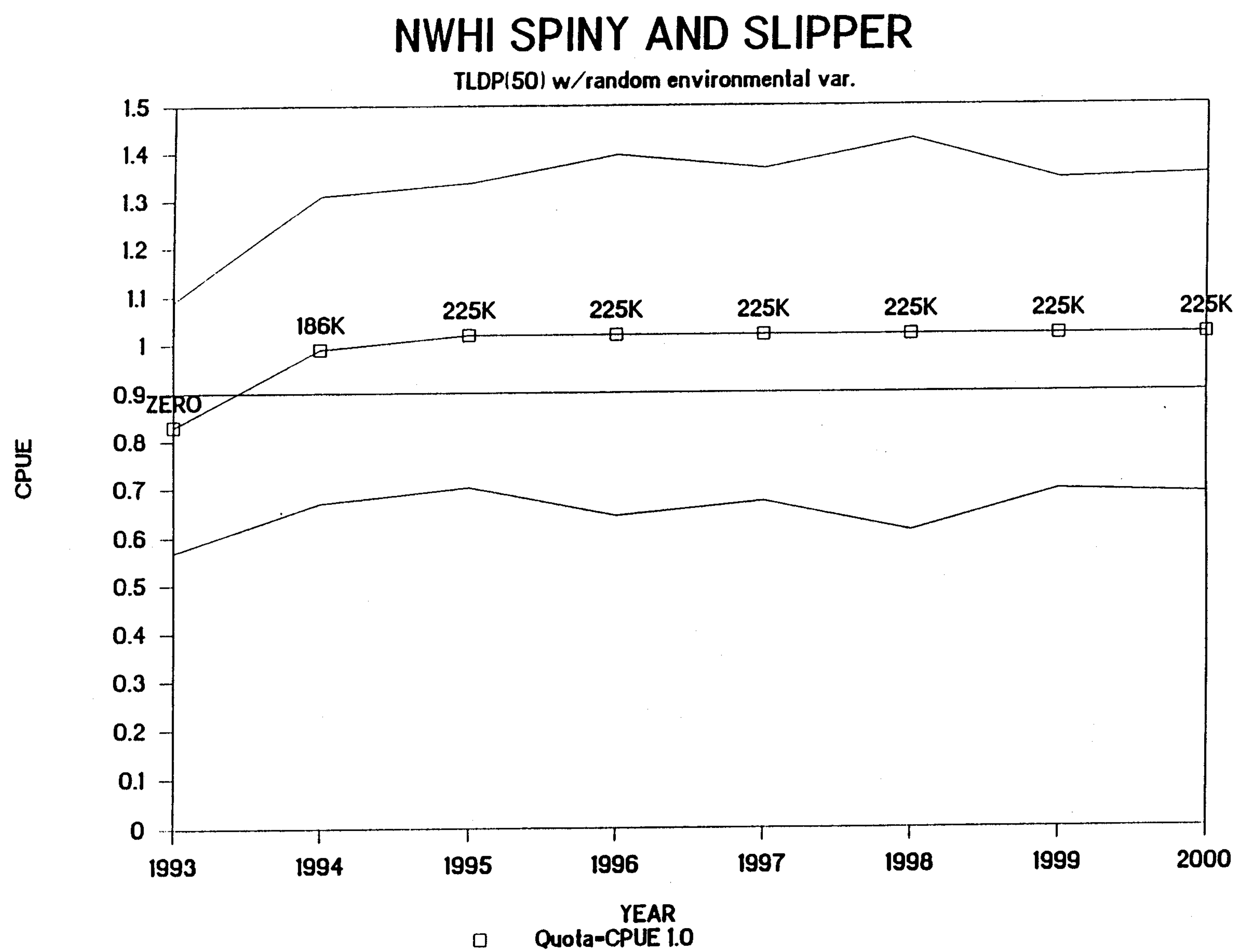

Figure 10. Simulation of commercial CPUE and quota levels, incorporating stochastic recruitment variation. The upper and lower horizontal lines represent the bounds of the 90% confidence limit of CPUE estimates. The solid horizontal line at a CPUE of 0.9 represents the minimum July CPUE level required for a viable commercial fishery in any given year.

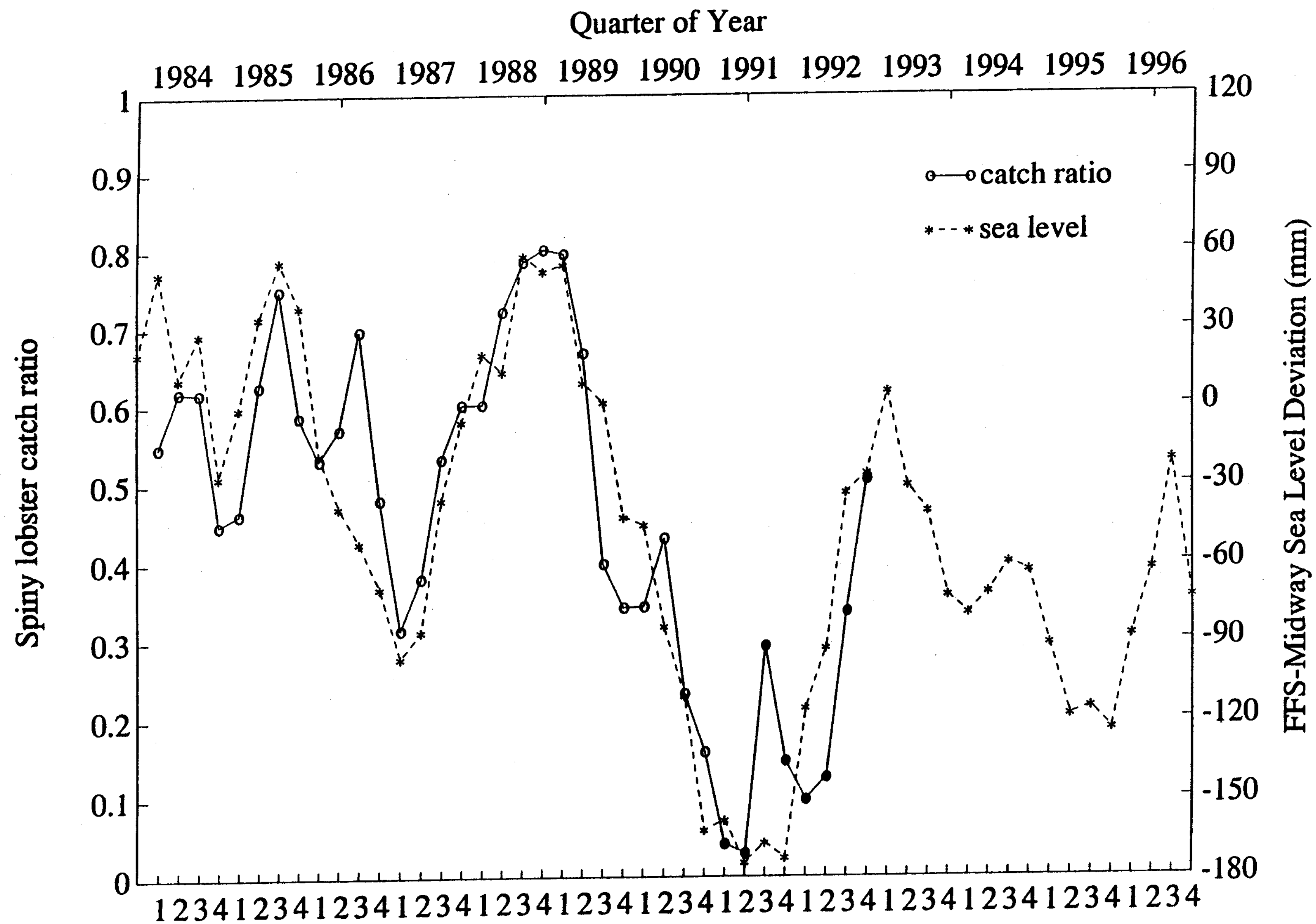

Figure 11. The ratio of landings of spiny lobster at Maro Reef to spiny landings at Maro Reef+Necker Island (o) overlaid with French Frigate Shoals-Midway sea level (*) advanced by 4 years. (after Polovina and Mitchum 1992)